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VEGETABLE PARASITES OF THE TEA PLANT.

THE BLIGHTS.

BY

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This is the first of a series of articles dealing with the above subject. The purely scientific descriptions of the various diseases will be omitted.

The title and the arrangement of the subject matter is that applied to chapters XIX, XX, XXI of Messrs. Watt and Mann's book on "The Pests and Blights of the Tea Plant" published in 1903 to which the writer intends to refer many times. No plates will be issued but coloured photographs of the more important diseases are being made, plates will be prepared from these and published subsequently.

The authors of "The Pests and Blights of the Tea Plant" point out that their list of vegetable parasites is by no means complete. They state that "the more important parasites may be said to be two or three fungi found on the leaves, a fungus and an alga on the stems; and two, at least, species on the roots."

Since the above paragraph was written between 20 and 30 fungi have been found attacking tea leaves, about the same number on the stems and a dozen or so on the roots. All these have received careful study. Any of these fungi may under favourable conditions cause severe damage. It is therefore necessary to keep a constant watch. Most of them individually cause little damage and in the course of our investigations it has been found that many of the attacks of fungus disease are the result and not the cause of the lack of vigour of the infected plants. The tendency of our research in more recent years has been to pay more attention to making the tea plant healthy than to curing its diseases individually. Im-

provement in the vigour of the plant unfortunately does not render it immune to all diseases and it is necessary in such cases to devise additional treatment. The direct treatment of disease is costly and the profit is more or less limited to the elimination of the loss due to the disease in question. Indirect treatment of the disease by increasing the vigour of the tea plant is far more profitable. It has been the policy of this department to limit the application of direct fungicidal treatment to those diseases which fail to respond to treatment by improving the vigour of the tea plant. The sole object in treating fungus disease is to increase the profits of tea culture by reducing the losses due to the diseases concerned. The application of a treatment which costs more than the disease is justifiable in cases where it is possible to avoid a greater loss by preventing the disease in question from attacking large areas. In the case of many of the diseases of the tea plant this is not possible as other plants outside the control of the planter harbour the same fungus. Under such circumstances it is more profitable to treat the tea plant and endeavour to improve the yield in spite of the disease. To illustrate this point let us suppose that a section of tea yielding five maunds per acre is attacked by Brown blight and the yield is reduced ten per cent. It is possible to keep the Brown blight in check by direct fungicidal treatment but the cost of such treatment would be not less than twenty rupees per acre. This amount would in many cases be more than the value of the tea saved. As the fungus which produces Brown blight is very common on other plants besides tea it would be necessary to continue the treatment indefinitely. Under these circumstances it would be more economical to spend the money on suitable manures, etc., with the object of increasing the yield. The effect of the manuring will be cumulative and although the blight may still take ten per cent. of the crop the section will yield a bigger profit. Suppose the yield is eventually increased to ten maunds per acre. As the cost per acre of fungicidal treatment would be very little more than that required for an area yielding five maunds, it would then be profitable to carry out the treatment as the in-

crease in crop would show a profit on the expenditure. It is obvious from the above that it would be foolish to issue general recommendations. It is the duty of this department to find out the life histories of the fungi concerned and by making use of this information devise methods for keeping them in check. It is also necessary to ascertain the special conditions favourable to the fungi concerned so that suggestions may be made for the modification of cultural operations such as manuring, pruning, etc., with a view to rendering the tea bush less susceptible to attack.

For reasons mentioned above it is however for the planter to make the final decision as to the advisability of carrying out the suggestions offered.

This is of course not very satisfactory to the Mycologist as it is often difficult to see how much of the improvement in the yield of a particular section is due to his researches. However, as the yield per acre of tea in North-East India continues to increase it will be increasingly possible to improve it still further by direct fungicidal operations. With this object in view considerable research has been carried out on spray fluids and methods for their application on a large scale.

There are a number of more or less important vegetable enemies of the tea plant which will be taken up before those which cause "diseases."

Loranthus Sp. "ROGAMULLA."

In the forests of North-East India one frequently sees clumps of branches resembling mistletoe growing on the trees. These are also found on the tea plant particularly in the seed gardens. At the time Watt and Mann wrote they were very frequently found there but now-a-days it is only in badly neglected ones they are noticeable. These clumps are, like the mistletoe, a parasitic growth.

Rogamulla is found everywhere in the tea districts but it only causes damage on neglected seed gardens. With very

little attention it is possible to keep it in check by cutting off the infected branches. The roots of the Rogamulla extend for a long way below the point at which its leaves and stems show themselves and it is therefore necessary to cut well below this point. Various interesting things regarding this plant have been found out. The seeds do not germinate unless they have passed through a bird's intestines. The leaves of the Rogamulla are modified by the nature of the host plant. If the parasite is growing on a tree which bears narrow leaves its own leaves grow narrow. When growing on a broad leaved tree they grow broad, the shape of the leaves is even modified by the shape of the tea plant on which the parasite happens to be growing. On some jungle trees Rogamulla has been seen to replace the whole of the normal foliage but when this happens both the host and the parasite die within a few years.

FERNS AND OTHER PLANTS IN THE BUSHES.

Watt and Mann point out the desirability of removing ferns, ulu grass, etc., from the middles of the bushes. This is now usually done as a part of the general routine.

LICHENS AND MOSSES.

At the higher elevations of the Darjeeling district the tea bushes support a veritable garden of lichens and mosses. These are not parasitic but they interfere with the growth of the plant to which they are attached by offering mechanical resistance to the expansion in circumference of the stems. They also harbour insect pests. In Darjeeling the moist cool climate favours their growth and active measures for their removal are desirable. In other districts the lichens and mosses are only present to an injurious extent on bushes which owing to their poor condition make very slow growth.

Lichens are not individual plants but the result of the association of two kinds of plants—fungi and algae. For instance, in damp shady places old leaves may be observed to bear

on their upper surfaces a number of spots. The orange coloured ones of the red rust alga, black ones caused by a fungus and grey ones. The last ones are the result of the red rust alga growing in co-operation with the black fungus thus forming a lichen—which looks quite different from either. All these spots may be rubbed off the surface of the leaf. They are not parasitising it.

Remedy: Badly hide-bound plants require to be nursed back to good health by judicious manuring, pruning, etc. Their improvement may be considerably accelerated by spraying with Lime sulphur solution but the spraying alone will only effect a temporary improvement. In order to obtain permanent results it is necessary to increase the vigour of the bushes.

Except in comparatively few areas, *e.g.*, the higher elevations in Darjeeling, epiphytic plants are not now-a-days produced in sufficient quantities to warrant special measures for their removal. In Darjeeling however the application of strong Lime sulphur solution followed by rubbing with sacking, a coco-nut husk or even wire carding brushes (in extreme cases) have been used with success. Firing the section before pruning as suggested by Watt and Mann is now seldom carried out as such severe measures are not necessary.

Parasites and Blights on the Leaves.

Pestalozzia theae, Saw.

GREY BLIGHT.

Refs:—Watt and Mann, "The Pests and Blights of the Tea Plant," 2nd ed., p. 380.

Butler, "Fungi and Disease in Plants," p. 451.

Petch, "Diseases of the Tea Bush," p. 27.

Indian Tea Association, "Quarterly Journal," 1920, Part IV, p. 152.

Watt and Mann give the name as *Pestalozzia guepini* Desmaz. The same fungus was subsequently considered to be *Pestalozzia palmarum*. It has, however, since been proved that the species, which normally attacks tea, is a distinct one which has been named *Pestalozzia theae*, Saw.

The disease is common in all districts.

History :—According to Watt and Mann, it was mentioned by Mr. M. C. Cooke, who examined samples from Cachar, in 1873. It has since been found in every district in which tea is grown. Even the new tea districts of Africa are not free from it. It is obvious therefore that the fungus is a very common one and although only one species has been found to attack tea that species also attacks a number of jungle plants in North-East India, e.g., Nahor, *Mesua ferrea*.

Description :—Grey blight is one of the commonest blights of tea leaf. It is rarely so serious as Brown blight which it closely resembles in appearance. It usually attacks the leaves but is also sometimes found on the stem of the tea plant. The portions attacked by the fungus die forming grey patches on the upper surface. These patches when young are brown. Their edges are sharply defined by a ring of deeper brown colour and may often be marked with delicate concentric rings, alternately light and dark brown. The under surface of the leaf does not usually turn grey. The blight first appears on the upper surface of the leaf as minute brownish spots. These spots enlarge and several spots may coalesce to form one large irregular patch. Minute black dots or pustules (the acervuli of the fungus) are often seen, arranged in concentric lines, mostly near the margin of the diseased spot, on the upper surface of the leaf. Sometimes they are scattered irregularly, over both the surfaces of the spot. Some of the dots coalesce to form black crusts.

The black dots, on the diseased patches, due to Grey blight are, as a rule, much larger than those of Brown blight. Examined by a pocket lens, the dots will be seen as crater-like openings and, unlike Brown blight, are never surrounded by

ally hair. A cross section of a diseased spot when examined under the microscope will show that the pustules are formed underneath the skin. The pustules arise from a collection of mycelium which develops into bowl or cone-shaped, thin wall-ed spore cases. From the cells of the inner wall of each spore case stalks grow out and form at their tips spindle-shaped cells which are separated from the stalks by cross walls. These spindle-shaped cells, the spores of the fungus, are further divided by four cross walls into five cells, with the three central ones larger and darker than the single colourless cell at each end. The terminal cell gives rise to three or four colourless thread-like projections each ending in a blunt knob. These spores, in the course of their development, push their way through by rupturing the skin of the leaf. The spores are distributed by wind, the hair-like projections at their tips acting as floats. Experiments on the dissemination of the fungus diseases by wind and other agencies, have shown that in the air round about Tocklai, Grey blight spores are present in larger numbers than those of other common fungi attacking tea. The mycelium of the fungus grows between the cells of the leaf and within them. It is very fine and colourless and with many divisions.

Watt and Mann refer to the black dots as "*Perithecia*." This term is now used to denote another particular type of fungus fructification. According to the nomenclature, now in common use, the clusters of spores forming the black dots are termed Acervuli, derived from the Latin word *Acervulus*—a little heap.

In another paragraph the same authors make the following observations:—

" It very often happens that these brown and grey patches
 " commence near the base of the leaf, and this is one of the most
 " alarming forms of the disease, for then the leaf will turn
 " brown and drop off apparently without visible blight,—for the

“ fungus has only attacked the leaf stalk and extreme base of the leaf. The attack may commence, however, on the apex, or on the margin, or two or three patches may form at once and extend till they unite, when the entire leaf may assume a dirty whitish grey colour.

“ It seems possible that a second form of the fungus reproducing by a different method without the intervention of spores, may exist. A diseased leaf drops into contact with a healthy leaf below, and where they touch become cemented by a tuft of fungus filaments, which are the basis for a new attack. This appearance has not yet been thoroughly investigated. It is however, known that Grey blight is what is called a ‘form-genus,’ that is to say, another and higher form of the fungus exist, most probably living on dead leaves. The fact that such a form probably exists renders it absolutely essential that dead and dying leaves, whether on the bush or on the ground, should be destroyed.”

This description closely resembles that of Black rot and it is probable that this disease was confused with Grey blight.

Depredations :—True Grey blight causes little damage to vigorous tea. The epidemic form, mentioned by Watt and Mann, is almost certainly Black rot. The mistake was readily excusable as the Grey blight fungus very frequently attacks leaves which have been injured by Black rot. Where true Grey blight is prevalent, it is an indication of unsatisfactory conditions of the soil.

Remedies :—The cause of the weakness must be sought for and remedied. The blight will meantime disappear. Whenever a section of tea is badly attacked by a disease which appears to be Grey blight, no time should be lost in consulting this department as in all probability the disease is not Grey blight at all.

Glomerella cingulata, Stonem.—*Colletotrichum camelliae*.

THE BROWN BLIGHT, MASSEE.

Refs :—Watt and Mann, "The Pests and Blights of the Tea Plant," 2nd ed., p. 385.

Butler, "Fungi and Disease in Plant," p. 448.

Petch, "Diseases of the Tea Bush," p. 31.

Indian Tea Association, "Quarterly Journal," 1920, Part II, p. 37.

Found in all tea districts.

History :—Brown blight was noticed here and there all over the tea districts in North-East India in 1895. It was also found in Ceylon about the same time. It has since been found wherever tea is grown.

Description :—Brown blight attacks the leaves and green stems of the tea plant. The fungus infects the leaf when it is quite young. A tiny tube from the spore enters the skin and the contents of the spore pass into one of the cells of the skin and there remains dormant until for some reason or other the condition of the leaf favours the further development of the fungus. The portions attacked by the fungus die, forming patches yellowish to chocolate brown above and light brown below. The edges of these patches are sharply defined and commonly marked with a delicate concentric zonation consisting of narrow lines and darker bands. Several spots may coalesce to form one large irregular patch. Minute black dots or pustules (the acervuli of the fungus) are seen arranged in concentric lines on both sides. On some of these spots may be seen milky or pinkish drops. These are masses of spores or seeds of the fungus. This disease is often confused with Grey blight which it resembles. The black dots on the diseased patches due to Grey blight are, as a rule, much larger than those of Brown blight, but sometimes it is difficult to distinguish these diseases without a microscope. Examined by a pocket lens these dots will be seen as crater-like openings, some of which

are surrounded by deep brownish-black hairs or papillæ. A cross section of the diseased spot when examined under the microscope will show that the pustules are formed beneath the skin and later push their way through, by the development of a mass of mycelium, covered with cone-shaped erect hyphæ or filaments. The end of each hypha or filament swells slightly and later is separated from the rest by a wall. The detached portions correspond to the seeds of higher plants and are called spores. This particular kind of spore is called a conidiospore. One or more conidiospores are produced from a single hypha. These spores have a gelatinous coat and they often stick together and emerge as a milky or pinkish exudation. The spores stick to insects, like red spider or green fly, cattle, the clothing of coolies, etc., and are thus distributed. They are oblong with their ends rounded, colourless, one-celled, rarely two-celled. This imperfect stage of the fungus was for a long time the only known fruiting stage. It was known as *Colletotrichum Sp.* and *Gloeosporium Sp.* When the blackish hairs mentioned above were present the fungus was called *Colletotrichum Sp.* When no hairs were found it was called *Gloeosporium Sp.* The fungus however seems to be identical. There are species of *Gloeosporium* found on tea but they have smaller spores. There are also various strains of the Brown blight fungus, some of which develop few hairs.

At a later stage the surface of the spot bearing the conidial form of the fungus becomes light grey and covered with black dots. If a section be cut across such a spot and examined under a microscope it will be seen that these black dots are the crater-like openings of spherical receptacles called perithecia. The perithecia are never surrounded by any dark hair like acervuli of the conidial form. The perithecia, produced singly or in groups, remain embedded in the tissue with their mouths only projecting. The perithecia are nearly spherical, and occasionally with short beaks. They are black. They contain a large number of club shaped sacs (asci) each of which contains eight spores. These spores are called ascospores. The ascos-

pores are one-celled, colourless, slightly tapering towards their ends and usually slightly curved. They are arranged in two rows within the ascus. The interior of the beak of the perithecia is covered with hairs. These hairs have an important function as they regulate the escape of the spores. It is most common during January to July, *i.e.*, during the cold weather and early rains.

This form of fructification is identical with that of the fungus which cause ripe rot of many fruits. This fungus has been called *Glomerella cingulata*, Stonem. The two forms often occur on the same leaf and in one case the spores of the *Glomerella* form were observed to have germinated and producing the *Colletotrichum* form. In pure culture, each form is readily produced from the other. Watt and Mann only refer to the *Colletotrichum* form but point out that another form is probably produced in decaying leaves.

Depredations :—This blight only attacks leaves which have been weakened by other causes. Brown blight is sometimes very serious indeed and the loss in crop due to a severe attack is very considerable. It is more commonly serious on unpruned than pruned tea and is frequently one of the causes of disappointing yields especially when weather conditions are unfavourable, either too dry or too wet. It only causes serious damage on weak bushes. In some districts notably the Dooars and Terai it is one of the commonest diseases and in conjunction with other fungi and insect pests causes considerable loss. No case has been observed in which Brown blight alone may be said to have caused the damage. It is almost invariably associated with red rust and frequently with species of *Corticium* also.

Remedies :—As the disease is always associated with lack of vigour in the infected bushes and the fungus which produces it is a very common one, it is obvious that direct fungicidal treatment will only have a temporary effect. The most reasonable way to deal with attacks of this disease is to ascertain the cause of the weakness of the bushes and remedy that.

There are cases, however, where Brown blight and other diseases associated with the weakness of the bush are so severe that it is necessary to apply direct fungicidal treatment to check the diseases, sufficiently to allow the bushes concerned to take advantage of improved conditions within a reasonable time. It should, however, be emphasized that the direct fungicidal treatment of Brown blight is mere waste of money if the conditions, responsible for lack of vigour of the bushes, are not dealt with also.

Spraying with Lime sulphur solution, see Quarterly Journal, Part IV, 1926, has been proved to be a satisfactory method of checking this disease. On account of the cost, both in money and labour, spraying is only recommended when the attack is so severe that the improvements, in manuring, pruning and cultivation, are not likely to produce the desired effect, unless the disease is checked. On many gardens in the Dooars and the Terai districts Brown blight, in association with other diseases, is causing such severe damage that the bushes fail to respond to cultural improvements. In such cases spraying with Lime sulphur solution is recommended even where the immediate addition to the crop does not cover the cost. It may even be necessary to continue the spraying at a loss for some years, until the cultural improvements have increased the vigour of the bushes sufficiently to enable them to withstand the attacks of the disease.

There are cases where for some reason or other spraying is impossible. In those circumstances the loss to the plant due to the diseases can be compensated for by allowing it to grow more leaf. In other words by leaving it unplucked after pruning and manuring. Some planters hold the erroneous opinion that the same effect can be produced by leaving the bushes unpruned. Observations have shown that this is not the case. The removal of much of the diseased and moribund wood tends to strengthen the bush if it be allowed to remain unplucked. In most cases the desired result may be obtained by manuring

and pruning the bush and leaving it unplucked for one year. In extreme cases it may be necessary to leave it unplucked for a second year. The bushes should always be pruned again at the end of the first year and needless to say the manuring should be continued indefinitely.

RIM BLIGHT.

Refs :—Watt and Mann, "The Pests and Blights of the Tea Plant," 2nd ed., p. 386.

Butler, "Fungi and Disease in Plants," p. 455.

Petch, Diseases of the Tea Bush," p. 39.

Indian Tea Association, "Quarterly Journal," 1916, Part II, p. 85, and 1918, Part II, p. 27.

1918, Part II, p. 27.

Found in Upper Assam.

History :—This disease was first mentioned in the first edition of "The Pests and Blights of the Tea Plant" published in 1898. In the second edition it is attributed to the combined attack of the fungi which cause Brown and Grey blights. Later the writer attributed it to species of *Alternaria* and *Cladosporium*. Various other fungi have also been found in association with this disease.

Description :—The blight first appears on the young leaves. The serrations turn brown. As the leaf grows the browning extends inwards and as the portions remaining green continue to grow the leaf becomes wrinkled with the edges curled downwards. In the meantime the brown portion continues to extend until finally most of the area of the leaf dies. When the attack is severe all the young growth may be destroyed. The blight is only found on the young succulent growth produced early in the season. It has never been observed at other times of the year.

Recent researches have shown that the attacks of fungi are not the cause but an effect of the disease. In the early stages the dead tissue is quite free from fungi. Examination of the

stems and roots of the bushes on which the disease appears has revealed the presence of no fungus or other parasite likely to account for the condition.

The disease is serious only on light leafed varieties of tea. Investigations show that at the same time the disease appears on the light leafed varieties the growth of other varieties in adjoining sections is also checked although the disease does not attack them. It appears that the disease only occurs when in the early part of the season a period of good growing weather is succeeded by a period of bad growing weather. The weather may be either too dry or too wet. The blight is more serious on cut back or heavy pruned than on light or unpruned tea.

Depredations :—A bad attack of the disease may cause the loss of all the new growth. When the weather conditions improve the growth is gradually renewed and by July or August no trace of the trouble is usually noticeable.

Remedies :—As the disease is the result of climatic conditions it is impossible to do much when a section is actually attacked. If, however, experience shows that certain sections of tea are particularly liable to attack something may be done to prevent recurrence. It has been found by experience that shade reduces the tendency to attacks of this disease but it takes some years to establish shade trees. In the meantime it is possible to avoid the production of very succulent leaf at the time of the year when the weather is usually very uncertain. This may be done by carrying out cutting back and heavy pruning very late in the cold weather. It is questionable however whether the loss due to the lateness of the pruning will not be just as great as that due to the Rim blight. The recovery from Rim blight may be accelerated by manuring with readily available manures immediately the disease appears. Nitrogenous manures appear to be particularly suitable for this purpose.

THE MANUFACTURE OF GREEN TEA.

BY

C. J. HARRISON.

There are several gardens in North-East India on which the manufacture of green tea is carried out during the whole, or part, of the season. The entire exclusion of the withering and fermenting stages necessary to the manufacture of black tea, renders the whole process of manufacture of green tea a simple one in comparison with that of black tea, variations in weather conditions exercising little effect on the manufacture of the former type of tea.

While this is so, green tea making requires as much, if not more, care and supervision than does black tea manufacture, since the plea of unfavourable weather conditions cannot be advanced as an excuse for poor quality of the unfermented product.

Theory. The theory of the manufacture of green tea is as follows :—

In the modern process the tea leaf undergoes a process of steaming whereby all the chemical changes connected with withering and fermentation are checked. These changes ordinarily go on under the influence of complex substances called enzymes, and it is the destruction of these latter in the steaming process which prevents the wither and fermentation from taking place. The succeeding processes of centrifuging, rolling, drying, and sorting are, so far as can at present be ascertained, connected with no chemical change and merely bring the leaf into a suitable condition for the market. It will be realised, that, with the om-

mission of the withering and fermenting processes, the time taken in manufacture, from the time the leaf comes into the factory to the time it leaves the dryer after the final firing to 16 annas, is scarcely more than two hours, as against an average of 24 hours for the manufacture of black tea.

Since mechanical stalk extracting is a very difficult process to carry out satisfactorily on green tea, it is essential that good quality leaf with small shoots shall be plucked. Leaf attacked by red spider or mosquito shows up clearly in the infusion as red or discoloured leaf, and as such, detracts considerably from the value of the tea, which should give a completely green infusion.

The practice of pressing down the leaf in the plucking basket or in leaf gharries is a bad one and should always be discouraged since it causes the leaf to heat up, and results in reddening. This reddening is a sign of chemical withering having taken place and in consequence the liquors of the leaf made may have an orange or reddish appearance. In addition the infused leaf is reddish. Such teas command much lower prices than those giving bright green infusions and pale greenish-yellow liquors.

Often the evening leaf is not manufactured at once but is spread about 6 inches deep in a cool place, *e.g.*, on the floor of the fermenting room (which will be out of use at the time, if black tea is not being made). As early as possible next day, this leaf is steamed and manufactured. If, as often happens, the night has been hot, some withering takes place, and teas made from leaf kept overnight are poorer in quality than teas made from leaf manufactured immediately. Much can be done to arrest any withering while the leaf is on the floor of the fermenting house, by spraying it with clean water. For this purpose, ordinary garden sprayers or syringes with fine nozzles are very convenient. If the leaf comes in saturated with rain water as a result of a heavy shower before or during plucking, spraying need not of course be resorted to.

During the middle of the rains, when the quality of black teas is at its poorest, the quality of green tea should be at its best, the humidity of the atmosphere preventing, to a great extent, any withering likely to take place before the steaming operation. Moreover, the leaf on the bush gets more shade during the rains, when not only are shade trees in full leaf, but the weather is naturally more cloudy. This excess of shade produces better quality of leaf for green tea, and the final product has a deeper green colour.

The first operation, namely steaming, is carried out in a cylindrical drum of wood or metal, rotating on its longer axis at about 15 r. p. m. The charge is about 200 lbs. of green leaf, and the length of time each charge is steamed—is from 2 to 3 minutes. Steam at 20—30 lb. sq. in. pressure is led into the drum at either end, the steam pipes forming the spindles on which the drum rotates. As each charge is finished it is emptied out on to the floor and cooled with cold water. Two charges, *i.e.*, 400 lbs. of green leaf, are then put into a centrifugal machine, or hydro-extractor, revolving at about 1,000 r. p. m., and a considerable quantity, about 15 gallons, of yellowish liquid is expressed. This liquid contains about $\frac{1}{2}$ lb. per gallon of solid matter, of which $2\frac{1}{2}$ ozs. is tannin and $\frac{1}{2}$ oz. is caffeine.

After centrifuging for about three minutes the leaf is removed and rolled with no pressure.

The length of time of this roll varies in different factories from ten minutes to half an hour. After rolling, the leaf is put through a dryer, and dried off to a degree which varies considerably in different factories. In some factories it is dried only to about six annas, and in others to a degree just short of crispness. The semi-dried leaf is rolled again and kutchra sifted. A suitable scheme for rolling is 20 minutes medium pressure with a kutchra sift, then 40 minutes medium heavy pressure followed by another kutchra sift to break up the balls of leaf.

The leaf is then dried either in one or two operations. In one factory the drying is done in a Gibbs and Barry machine at 180°F making 4—5 r. p. m.

In another, the drying is completed in two operations, the first in an Empire at 220°F. to 12—13 annas, and the final one also in an Empire at 200°F. to 16 annas.

The “rough mal” is a dark olive green colour and stalk shows up almost white. This is picked out by hand from the cut mal, as the use of a mechanical stalk extractor causes flakiness, and gives, instead of twisted grades, a large percentage of a grade similar in appearance to the Souchong of black tea. Such a grade is undesirable and would get only a low price in comparison with well twisted Hyson.

After sorting, the teas are in some factories given a polish by placing the tea in a narrow cylindrical iron drum with 1 per cent. of French Chalk, and rotating the drum for about two hours. This process is also called “glazing” or “facing.” In some factories, especially those who make teas for the American market, “facing” is left out, the teas being sent away without any polish.

A few years ago the polish used often contained Prussian Blue and turmeric in addition to French Chalk or soapstone, to improve the colour of the tea; this practice however is now generally discarded as the constituents of the polish are considered harmful.

The following are typical green tea grades :—

Fine Young Hyson; Young Hyson; Hyson No. 1; Hyson; Twankay; Fannings or Soumée; and Dust.

In one or two gardens, the Hysons are combined into one grade called Young Hyson, which forms about 90 per cent. of the invoice. The remaining 10 per cent. is made up of 2

per cent. Twankay, 3 per cent. Fannings, and 5 per cent. Dust. The following tables show tannin and caffeine percentages in typical green teas :—

Grades.	Percentage made.	Total Tannin.	Total Caffeine.	Tannin in Taster's infusion.	Caffeine in Taster's infusion.	Moisture.
South Sylhet Garden.						
A Young Hyson ...	90½%	13.87%	3.42%	7.9%	2.71%	5.2%
Twankay ...	1½%	12.90%	1.46%	.....	.....	8.4%
Fannings ...	2½%	15.90%	1.40%	.....	.....	8.9%
Dust No. 1 ...	5½%	16.82%	2.20%	.....	.....	8.0%
B. Young Hyson ...	85-90%	13.69%	1.83%			5.2%
North Cachar Garden.						
Young Hyson ...	12½%	14.09%				
Fine Young Hyson	12½%	11.85%				
Hyson No. 1 ...	25%	13.23%				
Hyson ...	33%	15.29%				
Twankay ...	14%	12.89%				
Dust ...	3%	14.09%				

The total tannin in green tea is always higher than that of black tea made from similar leaf. The reason is that, during the fermentation of black tea, a certain percentage of tannin is converted into red and brown substances, some of which are not extracted by hot water and remain on the leaf, to give it the characteristic reddish brown colour. The longer the fermentation and the warmer and dryer the fermenting room, the greater is the production of insoluble brown substances, and therefore the lower is the tannin content of the final product.

This loss of tannin is not undergone in green tea manufacture since there is no fermentation, and a high tannin content in the final product results, the only loss being due to expression of juice in the hydro-extractor.

With regard to caffeine, there is no apparent reason why black and green teas should differ, but it is usually found that green teas contain more of this stimulating substance than do black teas.

In a cup of black tea there is little less tannin than in a similar infusion of green tea, but whereas in the former case some of the tannin is in the form of reddish brown, tasteless substances, we find in green tea liquors all the tannin in the form of astringent colourless tannin. The caffeine extracted in a cup of green tea is always considerably higher than that extracted in a cup of black tea.

The following figures compare total percentage of caffeine and tannin in black and green teas, and also the percentage of these products extracted in an ordinary taster's infusion.

Percentages of tannin and caffeine.

Black tea—B.O.P.		Green tea—Young Hyson.	
Total.	Extracted in a taster's fusion.	Total.	Extracted in a taster's infusion.
Tannin ... 13.0%	Tannin 7.20%	Tannin 13.9%	Tannin 7.9%
Caffeine ... 2.5%	Caffeine 1.20%	Caffeine 3.42%	Caffeine 2.71%

The leaf of green teas should be olive green with no trace of brown or red colour. There should be an absence of white or yellowish stalk. The grade should be even in size, well twisted and clean, *i.e.*, free from dust. Buyers for markets, such as the Kashmir market, attach much importance to the appearance of the leaf and generally prefer polished teas. For such markets the liquors are of less importance than the leaf appearance.

Liquors should be greenish yellow or lemon yellow, with no suspicion of redness, due to withering or fermentation having taken place. The liquors should be pungent or "piquant" and should remain quite clear when cooled down. The case is

directly the opposite with black tea liquors, which should "cream down" when cool. The infused leaf should be green with no suspicion of redness due to withering, fermentation or to discolouration of the leaf by red spider, mosquito or mechanical damage.

It is interesting to note that the weight of tea made from a given weight of leaf is less in the case of green tea than in the case of black tea.

One maund of black tea requires four maunds green leaf.

One maund of green tea requires five maunds green leaf.

It is difficult to account completely for this loss in making green tea, though much of it is due to the extraction of soluble solid matter in the juice which is centrifuged off after steaming.

References.

"Green Tea" by Chas. Judge.

"Tea in China" by Samuel Ball.

THE TEA RESEARCH INSTITUTE OF CEYLON.

The first Annual Report, recently published, of this newly established Experiment Station, makes interesting reading.

The Institute came into being at the beginning of March, when the Director took up his duties. Since then, three other officers have been added to the staff, an Entomologist, a Mycologist, and a Biochemist, while it is hoped to add an Agricultural Chemist to the staff shortly. As regards scientific officers, therefore, this Institute is already in the position to which our own Scientific Department had advanced when the Tocklai Experimental Station was opened in 1912, twelve years after the inception of the Department.

The Report states that difficulty is being experienced in obtaining a suitable site for an Experimental Station, and at present the staff is working in temporary quarters. In spite of this handicap, however, the Report indicates that a determined and successful effort has been made to initiate a comprehensive programme of work on both the culture and manufacture of tea, while the number of enquiries and specimens received from estates, in what was virtually the first half-year of the existence of the Institute, shows the interest taken in the venture by the planters in the island, and must be a matter of considerable satisfaction both to the staff and the Board of Control.

The Director, in reviewing the needs of the Tea Industry as regards scientific enquiry, emphasizes the need for investigation into the physiological processes of the tea bush. In this connection he makes a statement which might very well be turned into a "slogan," printed on cards, and hung in a conspicuous position in the office of every tea estate :—

THE TEA BUSH IS THE BASIS OF THE TEA INDUSTRY.

In the multitude of problems which confront the modern planter this axiom is apt to be overlooked.

The most serious problems demanding investigation in Ceylon, according to the Director, are those connected with pruning, and it is not difficult to see how this may very well be. In North-East India, except in the hill districts of Darjeeling, the general practice is to prune every cold weather. Of late years, for various reasons, considerable areas of tea have been left unpruned for a year, and one effect of this practice which has already made itself apparent is a slackening of the control on the condition of the bush exerted by the annual pruning.

In a district such as Ceylon, where it has been the custom, for years, to prune at very distant intervals, this slackening of control must have gone much further, and it is not surprising to find that now that the light of scientific enquiry has been focussed on the Ceylon tea bush the necessity for investigation into pruning methods is thrown into relief.

The Director of the new Institute is a mycologist of distinction and extensive Ceylon experience. The Mycologist is an officer who has already spent some years in the investigation of fungus diseases of tea and other plants in Ceylon, as a member of the staff of the Agricultural Department. The Entomologist and Bio-chemist are younger men, new to the island. It might therefore be expected that in the early stages of the Institute, at any rate, the reports will deal more fully with the mycological problems. This is the case with the first report, and the Mycologist submits an account giving interesting information on the Cercospora Leaf Disease, Chlorosis of Tea, Branch Canker, and Diseases of Tea Seedlings.

The Cercospora leaf disease is found on tea in North-East India, but the damage caused thereby is negligible. It is occasionally found on bushes growing on patches of unsatisfactory soil and is usually associated with Red Rust, Brown blight and Grey blight. It has been found in North-East India that this disease disappears when soil conditions are improved. The Ceylon Mycologist remarks that in Ceylon the disease is common only when the conditions are very humid. In our own tea districts the disease is only noticeable during spells of rainy

weather early in the season. When the rains set in it usually disappears, sometimes reappearing towards the end of the season.

The next reference in the report is to "Chlorosis of Tea." The Mycologist refers to a description of a disease described by Mr. Park, Assistant Mycologist to the Ceylon Department of Agriculture, as "Witches' Broom." This disease apparently resembles that known as "Apple foliage blight" in Upper Assam, but differs from it in two important points. In Ceylon the leaves become mottled with yellow, sometimes becoming quite yellow. This yellowing is not noticeable in "Apple foliage blight." In many cases indeed the leaves assume a darker colour than normal. Mr. Park also mentions abnormal branching in the Ceylon disease. This has not been observed in North-East India. The Mycologist points out that there may be three distinct diseases described as one disease by Mr. Park, tufted branches or Witches' Broom being characteristic of one, yellow and dwarfed leaves of the second, and the abnormal branching of the third. In order to avoid confusion on these points he suggests that the name "Chlorosis" be used only for the disease of which the yellowing of the leaves is the most prominent character. Chlorosis of tea occurs in fairly well defined areas in Ceylon and causes a very great diminution in crop and the death of a large proportion of bushes. In this disease the leaves become mottled and finally yellow. No organism was observed on the tissues. The disease does not appear to attack young plants and rarely makes its appearance before the bushes have been centred. It was observed that the acidity of the cell sap of the diseased stems and leaves was distinctly lower than that of normal stems and leaves. Experiments to determine whether the disease is infectious have been started and some very interesting results may be anticipated. No similar disease has so far been observed in North-East India, and Apple foliage blight, which may be the same as "Witches' Broom," is uncommon. It appears to attack only bushes of the Assam Indigenous jat and then only isolated specimens. It does not appear to be associated with soil conditions and does not appear to spread. One

specimen was watched for many years and none of its neighbours showed signs of attack. This specimen was sprayed, manured, pruned, etc., etc., without effecting any improvements in its condition. It was finally replaced and its successor is doing quite well. The only way of dealing with cases of Apple foliage blight in North-East India appears to be the removal and replacement of the bush concerned.

In connection with Branch Canker it is pointed out that the fact that organisms are present in decaying tea wood is no proof that they cause the decay. So far no two tea estates have yielded the same fungi, but the evidence at present available indicates that in the great majority of cases infection by organisms which leads to the rotting of tea wood occurs at the pruning cuts. A discussion on the use of antiseptics for the prevention of infection follows, and it is pointed out that the object of applying antiseptics such as tar is solely to prevent infection. It is not intended to encourage healing. The healing process is one of growth for which food material is required. Healing starts from the edges of the wound. The last part to be covered is the centre. The rot usually starts from the centre. For this reason the wound must be protected against invasion until the normal healing callosus can cover it. Effective prevention of wood rot in tea necessitates two distinct processes :—

1. The encouragement of healing by the application of suitable fertilisers and by the accumulation of food reserves within the plant before pruning.

2. The protection of the wounds by suitable antiseptic covers which will prevent the entry of rotting organisms until the wounds can be healed by the natural process.

From the statements made in this report it would appear that the pruning cuts do not heal so readily in Ceylon as they do in North-East India. This may be due to the Ceylon system of pruning. In our tea districts stem-rotting fungi cause serious damage only on old tea which has been cut back severely. The damage is reduced very considerably by :—

1. Preparing the bushes before pruning by manuring.

2. Allowing the bushes to produce ample growth following severe pruning. On some sections it has been found desirable to leave the bushes unplucked for a year following heavy cutting back. Where this has been done the cuts have healed very satisfactorily without any special antiseptic treatment, and the loss in crop in the first year is then more than compensated for by the extra leaf obtained in subsequent years.

By careful management it is possible to reduce to a minimum the necessity for pruning severely, but for a number of years to come, even in North-East India, it will in certain cases be necessary to cut back on to old hard wood, and a satisfactory antiseptic for application to the cuts would be a boon. So far nothing really satisfactory has been found.

The report then deals with seedling diseases. The Mycologist points out that in order to deal with many of the diseases associated with tea seedlings it is necessary to have a greater knowledge of the optimum conditions for the growth of the host plants. Chemical and physical analyses of soils provide insufficient data and considerably more attention must be given to the physiological condition of the plants themselves. Some experiments of a purely physiological nature have been initiated.

In our own tea districts it has been found repeatedly that improvement in the condition of the tea bushes brought about by improving soil conditions, pruning, etc., has overcome disease. In the course of time, as our knowledge of the conditions favourable to the growth of the tea plant is increased, it will in all probability be found possible to reduce the damage done by most of the fungus diseases to a negligible quantity.

The physiological investigations undertaken by the Mycologist therefore promise results of great interest and importance.

The Report of the Biochemist, who had been in the island only four months or so when the report was issued, deals mainly with preliminary work necessary to get his laboratory into working order and to test the value of different experimental

methods, but observations are already being made to determine the seasonal changes in the composition of the tea leaf, and the effect of withering on its water-soluble constituents.

An interesting section of the report, to those acquainted with the insect pests of tea in North-East India, is the section contributed by the Entomologist, affording evidence, as it does, that the main problems confronting the tea entomologist in Ceylon are very different from those he has to deal with in North-East India.

There is, for example, no mention of the tea mosquito bug, thrips, green-fly, looper, red slug, or of any related insect, while red spider only obtains casual mention. Thus few of our most important insect pests appear to be troublesome in Ceylon, while those most troublesome in Ceylon are of less importance here. Termites form an exception, being troublesome in both countries, but as it is stated in the report that the study of those insects is being undertaken by the Government Entomologist, their omission from the report is explained.

Tea tortrix, a pest of little moment here, is severe in Ceylon, and, although not perhaps so intense in its attacks as formerly, is gradually spreading over a large area, and also extending its range of food plants.

Shot-hole borer, a serious pest in Ceylon, but unknown in North-East India, is gradually receding in importance owing to the adoption of appropriate manurial treatment of the affected bushes.

Nettle-grub outbreaks occur locally, as in North-East India. Parasitisation by ichneumons appears to keep them in check, as is often the case in our districts.

The role played by red spider in North-East India would appear to be taken, in Ceylon, by the scarlet mite, though the purple mite is apparently more widely distributed. Yellow mite is abundant locally, but of minor importance.

Brown bug, lobster caterpillar, and a small bagworm are also recorded, and also, which is of considerable interest, the common Albizzia caterpillar, *Terias silhetana*. This latter caterpillar, with which is associated, less commonly, *Terias hecabe*, is very common in North-East India, and occasionally causes great damage to green crops, dhaincha (*Sesbania aculeata*) in particular. One case occurred in which 30 acres of dhaincha were entirely eaten down in three weeks. So far, however, perhaps fortunately, it has not, in North-East India, turned its attention to tea.

The red borer is described in this report as a nursery pest. It would hardly be described as such in North-East India, for although found in nurseries which are left for two or three years to obtain large plants for infillings, the practice of planting out at six and twelve months old generally results in the nursery being removed before the plants are big enough to support the insect. In clearances, however, it is occasionally a serious pest. It is by no means uncommon, however, in old tea. Cutting back the affected stems, with prompt destruction of the grubs, is reported to be an effective control, and this is also the case in North-East India. The important point is to cut out the affected branch as soon as possible after the leaves show that it is dying. Delay gives the grub a chance to become mature and escape.

Cutworm is a nursery pest in Ceylon, as in North-East India. Results are given of control experiments with attractive baits, which indicate that sweet potato and cabbage leaves, placed in pits in the soil, may be of value as traps for those insects.

Eelworm is occasionally serious in nurseries, and experiments on control have been instituted.

This section of the report concludes with notes on various pests of Dadap, Albizzia, Gliricidia, and Boga medeloa.

A catalogue of the books and periodicals in the Library completes a report which affords every indication that tea in Ceylon is to be well served by its new Research Institute.

THE FIELD EXPERIMENTS AT TOCKLAI.

BY

E. A. ANDREWS.

No. 4. THE PLUCKING EXPERIMENT.

In a previous number of this Journal* a report was published dealing with the results obtained in this experiment to the end of the season 1924.

The present report deals with the observations made from that date to the end of 1926. The records of the yields have been continued, but in addition, during the two years under review, the prunings from five bushes in each line (bushes No. 2 to No. 6) have been carefully measured with a micrometer at the point of severance, and the diameters recorded, in order to obtain a measure of the thickness of the pruning wood obtained.

It had been intended, as mentioned in the previous report, to distinguish between prunings from the centre and sides of the various bushes, but this was found to be impracticable.

The shoots to be measured numbered several thousands, and it was soon observed that unless all were thoroughly dried before being measured errors of some significance would creep in. It was therefore necessary to spread the bundles of prunings in the sun for some months before taking the measurements. In order to have an estimate of the amount of shrinkage on drying, six shoots from each bundle were measured immediately, and again at intervals until thoroughly dry. It was thought that in this manner a correcting factor might be obtained to enable the diameter of the fresh prunings to be calculated from the measurements of the dry prunings.

In the tables included in this note the diameters given for prunings collected in 1925 and 1926 refer to the dry prunings,

* 1925, Part I, pages 12 to 24.

for the reason that the shrinkage of the shoots in drying was found to be extremely irregular. The percentage shrinkage of prunings collected in 1925 varied between 2 and 23, while that of prunings collected in 1926 varied between 5 and 56. It was therefore obvious that a figure obtained from six shoots could not be used as a correcting factor for the whole bundle, and the measurements of the dry prunings have been utilised for comparison.

This variation in the amount of shrinkage undergone by different shoots in drying is of some interest, and it is curious to note the high degree of shrinkage of prunings cut from the bushes in the cold weather of 1926, as compared with those cut from the bushes at the end of 1925.

Table I records the yields of the plots, calculated to maunds of made (pucca) tea per acre, for the years 1925 and 1926, and the total average yield of the bushes under each experimental treatment.

In this and succeeding tables the same abbreviations have been used as in the previous report, but for ready reference they are here explained.

6 means plucked to six inches, and then to a janum throughout the season.

6L means plucked to six inches, and then to a leaf throughout the season.

4L means plucked to four inches, and then to a leaf throughout the season.

BB + means broken back to the janum or leaf, as the case may be.

BB — means not broken back.

BJ + means that banjhies were plucked (one leaf being weighed and the rest thrown away).

BJ — means that banjhies were left on the bush.

TABLE I.

Yields in Maunds of Made Tea per acre.

Treatment.	Line.	1925		1926		Total Average Yield to date.
		Yield.	Average Yield.	Yield.	Average Yield.	
B B. B J.						
6 + +	{ 10 19 28	{ 10·7 10·2 8·5	9·8	{ 9·6 10·5 9·8	10·0	67·1
6 - +	{ 3 12 21	{ 12·1 11·7 11·3	11·7	{ 8·0 8·2 10·9	9·0	67·5
6 + -	{ 2 11 20	{ 11·4 10·7 9·8	10·6	{ 9·5 8·4 9·2	9·0	59·0
6L + +	{ 6 15 24	{ 9·8 8·3 8·8	9·0	{ 8·3 8·3 8·8	8·5	53·2
6L - +	{ 4 13 22	{ 9·7 10·9 7·5	9·4	{ 7·0 7·0 7·8	7·4	52·4
6L + -	{ 5 14 23	{ 8·8 8·5 7·5	8·3	{ 8·5 8·5 9·2	8·7	46·0
4L + +	{ 9 18 27	{ 9·8 8·5 8·2	8·8	{ 10·4 10·5 8·5	9·8	59·4
4L - +	{ 7 16 25	{ 9·1 8·5 9·2	8·9	{ 8·6 8·8 9·5	9·0	53·9
4L + -	{ 8 17 26	{ 9·5 9·5 7·5	8·8	{ 7·3 7·5 9·5	8·1	49·1

Table II records the diameters of the dry prunings at the point of severance, all prunings from each bush being measured and the results averaged, and the means of the averages for the three lines receiving similar treatment being then calculated.

TABLE II.

Thickness of the Pruning Wood.

Treatment.	Line.	1925		1926	
		Average diameter of prunings in inches.	Mean diameter in inches.	Average diameter of prunings in inches.	Mean diameter in inches.
6 B B. B J. + +	{ 10 19 28 }	{ .195 .191 .218 }	.201	{ .216 .248 .225 }	.230
6 - +	{ 3 12 21 }	{ .199 .195 .225 }	.206	{ .220 .247 .234 }	.234
6 + -	{ 2 11 20 }	{ .198 .209 .214 }	.207	{ .228 .242 .240 }	.237
6L + +	{ 6 15 24 }	{ .205 .193 .216 }	.205	{ .250 .240 .225 }	.238
6L - +	{ 4 13 22 }	{ .224 .218 .212 }	.218	{ .254 .244 .260 }	.253
6L + -	{ 5 14 23 }	{ .210 .226 .231 }	.222	{ .257 .242 .256 }	.252
4L + +	{ 9 18 27 }	{ .199 .212 .238 }	.216	{ .229 .250 .248 }	.242
4L - +	{ 7 16 25 }	{ .243 .217 .225 }	.228	{ .220 .237 .231 }	.229
4L + -	{ 8 17 26 }	{ .227 .197 .244 }	.223	{ .245 .250 .235 }	.243

The results will be discussed in a manner similar to that followed in the previous report, taking first the effect of the class of plucking on the yield of leaf and thickness of pruning wood, next the effect of breaking back, and then the effect of taking "banjhies."

The Effect of the Class of Plucking.

Table III gives the total yield to date in maunds per acre given by the three different classes of plucking, and the mean diameter of the pruning wood in 1924, 1925, and 1926.

TABLE III.

The effect of the different classes of Plucking.

Class of Plucking.	Yield to date in Maunds of Made Tea per acre. (1921-1926 inclusive)	Mean diameter of pruning wood in inches.		
		1924	1925	1926
6	64.5	.229	.205	.234
4L	54.1	.233	.222	.238
6L	50.3	.242	.215	.248

If this table be compared with the corresponding table in the previous report it will be observed that the yields, under the different systems of plucking, still maintain the same order. Plucking to six inches, and then to the janum throughout the season, has given the highest yield; while plucking to four inches, and then to a leaf throughout the season, has yielded more than when, with similar treatment, the initial plucking left six inches of new growth. That these differences are not due to the fact that they existed in 1924, while the yields have since been even, is shown by the total yields for 1925 and 1926, which are as follows:—

6	—	20.0	maunds of made tea per acre
4L	—	17.8	„ „ „
6L	—	17.1	„ „ „

At the same time, it will be noticed that plots 6L are now yielding practically the same as plots 4L, and if the yields for 1924, 1925 and 1926 be compared with those for 1921, 1922 and 1923, it will be observed that plots 6L have yielded more leaf, relative to plots 6, during the last three years than during the

first three years. The increase, however, did not occur gradually, but suddenly in 1924, and its significance is as yet doubtful.

The figures for the thickness of pruning wood show that in 1926, as in 1924, the thinnest wood was obtained on the bushes plucked to six inches, and then to the janum, and the thickest wood on those plucked to six inches, and then to a leaf. The figures for 1925, however, do not show this, as the thickest wood was obtained on the bushes plucked to four inches, and then to a leaf.

Reference to Table IV, however, shows that in 1925 the bushes plucked to four inches and then to a leaf gave, for some reason, an unusually low yield, falling to, if not below, the level of those plucked to six inches and then to a leaf.

TABLE IV.

The Effect of the different classes of Plucking.

Class of Plucking.	Year.	Yield in Maunds of Made Tea per acre.	Mean diameter of pruning wood in inches.
6	1924	9.9	.229
	1925	10.7	.205
	1926	9.3	.234
4L	1924	8.4	.233
	1925	8.8	.222
	1926	9.0	.238
6L	1924	8.2	.242
	1925	8.9	.215
	1926	8.2	.248

Thus the indication, afforded before, that thickness of pruning wood is correlated with the amount of leaf removed from the bush, rather than with the style of plucking adopted, is emphasised.

Those who perused the first report will remember that each experiment is triplicated, there being three series of bushes re-

ceiving each treatment. Table V gives the yield to date for each series, and it will be seen that the differences in yield observable on examining the effect of each treatment as a whole are equally evident in each series considered by itself. Not only so, but the total yields for 1925 and 1926, given in the same table, show the same result. This would appear to point to the fact that the differences observed are undoubtedly due to the style of plucking adopted, and that, taken over the six years for which the experiment has been carried out, it may be concluded, with justification, that, at Tocklai, plucking to six inches, and then to the janum, gives more leaf than either of the other treatments adopted, while the least successful, from the point of view of production, has been that which leaves most growth on the bush, namely, plucking to six inches to begin with, and then to a leaf for the rest of the season.

TABLE V.

The effect of the different classes of Plucking on the yield, as shown by each separate series to date.

Class of Plucking.	YIELD TO DATE (1921-1926 INCLUSIVE) IN MAUNDS OF MADE TEA PER ACRE.		
	First Series (lines 2 to 10).	Second Series (lines 11 to 19).	Third Series (lines 20 to 28).
6	55.2	54.4	54.8
4L	48.6	45.0	47.8
6L	43.7	44.1	41.5
Yield for 1925 and 1926 inclusive in Maunds of Made Tea per acre.			
6	20.4	20.0	19.9
4L	18.3	17.7	17.5
6L	17.3	17.1	16.5

In Table VI the results for the years 1925 and 1926 are tabulated in still greater detail, and from this table two deductions can be drawn.

TABLE VI.

The effect of the different classes of Plucking on the yield and on the thickness of the Pruning wood, as shown by each separate series in 1925 and 1926.

Class of Plucking.	Series.	1925		1926	
		Tea. Yield in maunds per acre.	Wood. Diameter in inches.	Tea. Yield in maunds per acre.	Wood. Diameter in inches.
6	First ...	11.4	.197	9.0	.221
	Second ...	10.9	.198	9.1	.246
	Third ...	9.9	.219	10.0	.233
4L	First ...	9.5	.223	8.8	.231
	Second ...	8.8	.209	8.9	.246
	Third ...	8.3	.236	9.2	.238
6L	First ...	9.4	.213	7.9	.238
	Second ...	9.2	.212	7.9	.242
	Third ...	7.9	.220	8.6	.247

First, it is evident that, so far as outturn goes, the results of one year's observations are not to be trusted entirely. In the case of the first and third series, the results are in agreement with those deduced from six years' observations, but in the case of the third series there is a discrepancy, the bushes plucked to six inches, and then to a leaf, having yielded more than those plucked to four inches, and then to a leaf, in 1925.

Second, it is evident that although, in the one year, increased crop appears to mean thinner wood, the results of one year, in this regard, cannot be compared with those obtained in another year. Whatever the relative yields were found to be, the wood was in all cases thicker in 1926 than in 1925, and, when one remembers that the shrinkage on drying was greater in 1926 than in 1925, the difference is emphasised. This increased thickness of wood occurred in all cases, whether the outturn was greater or less in 1925 than in 1926. This phenomenon can only be put down to the fact of 1926 being a more favourable year for the production of wood than 1925, but it is interesting to note that the average outturn per acre, for

the bushes under consideration, was 9.5 maunds in 1925 as compared with 8.8 maunds in 1926.

The effect of "Breaking Back."

The effect of Breaking Back is shown in Table VII.

TABLE VII.

The effect of Breaking Back.

Treatment.	Yield to date in Maunds of Made Tea per acre (1921 to 1926 inclusive).	Mean diameter pruning wood in inches.		
		1924	1925	1926
Broken back (BB +)	59.9	.228	.207	.237
Not broken back (BB -)	57.9	.237	.217	.239

The results show a slightly increased yield in the case of bushes on which the long shoots are broken back, as compared with the bushes on which they are left, but this increased yield is small, and, as the figures in Table VIII show, was not maintained in 1925. Here, again, thinner wood accompanies the increased yield, if the yield for six years be taken as a guide, yet this is discounted by the fact that in 1925 the reverse was the case, while in 1926 there is little or no difference in thickness of the pruning wood.

TABLE VIII.

Treatment.			Yield in Maunds of Made Tea per acre.	
			1925	1926
B B+	...	..	9.2	9.4
B B-	...	...	10.0	8.5

Table IX gives the results for 1925 and 1926 for each series of bushes.

TABLE IX.
The effect of Breaking Back.

Treatment.	Series,	1925		1926	
		Tea. Yield in maunds per acre.	Wood. Diameter in inches.	Tea. Yield in maunds per acre.	Wood. Diameter in inches.
B B+ ...	First ...	10.1	.200	9.4	.232
	Second ...	9.0	.199	9.8	.246
	Third ...	8.5	.224	9.0	.233
B B- ...	First ...	10.3	.222	7.9	.231
	Second ...	10.4	.210	8.0	.243
	Third ...	9.3	.221	9.4	.242

From this table it may be seen that in 1925 the increased return for the bushes which were not broken back was regular throughout all three series, while in 1926 the third series differed from the other two in that the bushes which were not broken back gave a higher yield than those which were broken back. A further curious observation is that, as a rule, thicker wood was obtained on the plots which gave the higher yield, the one exception again being the third series, in which, in 1925, the bushes giving the lower yield (broken back) carried the thickest wood. The one consistency shown in this table is that in all cases the pruning wood was thicker in 1926 than in 1925, whether yields were higher or lower.

Thus, it may be said that, speaking generally, the results as a whole show a small increase in crop due to breaking back, and a tendency to the production of thicker wood on the bushes which were not broken back, but that the results, when examined in detail, show such irregularity that the differences obtained can as yet hardly be regarded as significant. Certainly, in this case, thinner wood has not always accompanied increased yield.

In Table X the results are tabulated in still greater detail, to ascertain whether any of the different styles of plucking, combined with the breaking back, has caused irregularities to appear, which do not occur with other styles of plucking. This table shows conclusively that the irregularities occur, whatever the style of plucking with which breaking back is combined.

TABLE X.
The effect of Breaking Back.

Treatment.	Series.	1925		1926	
		Tea. Yield in maunds per acre.	Wood. Diameter in inches.	Tea. Yield in maunds per acre.	Wood. Diameter in inches.
BB BJ					
6 + +	First	10.7	.195	9.6	.216
	Second	10.2	.191	10.5	.248
	Third	8.5	.218	9.8	.225
6 - +	First	12.1	.199	8.0	.220
	Second	11.7	.195	8.2	.247
	Third	11.3	.225	10.9	.234
4L + +	First	9.8	.199	10.4	.229
	Second	8.5	.212	10.5	.250
	Third	8.2	.238	8.5	.248
4L - +	First	9.1	.243	8.6	.220
	Second	8.5	.217	8.8	.237
	Third	9.2	.225	9.5	.231
6L + +	First	9.8	.205	8.3	.250
	Second	8.3	.193	8.3	.240
	Third	8.8	.216	8.8	.225
6L - +	First	9.7	.224	7.0	.254
	Second	10.9	.218	7.0	.244
	Third	7.5	.212	7.8	.260

It is therefore obvious, that, so far as breaking back is concerned, the experiment has not yet been carried far enough to draw definite conclusions, although the results to date, taken as a whole, indicate that there is a tendency, with breaking

back, to a very small increase in yield, accompanied by a tendency to the formation of thinner pruning wood.

The benefit which has occurred from breaking back is, so far, doubtful, beyond the fact of its keeping the plucking surface down, thereby making the bush easier to pluck and the plucking easier to supervise.

The Effect of Plucking Banjhies.

Table XI shows the effect of plucking Banjhies.

TABLE XI.

The effect of Plucking Banjhies.

Treatment.	Yield to date in Maunds of Made Tea per acre. (1921 to 1926 inclusive.)	Mean diameter of pruning wood in inches.		
		1924	1925	1926
Banjhies plucked (BJ +)	59.9	.228	.207	.237
Banjhies left (BJ -)	51.4	.239	.217	.244

It will be seen that, as before, there is still an increased yield from the bushes on which banjhies were plucked, as against those on which banjhies were left, and that this difference in yield is considerable, being 8.5 maunds per acre in six years. This increase, as will be seen from table XII, is continuing, for, while in 1925 the yields from the two treatments were the same, in 1926 the bushes from which banjhies were plucked gave 4/5 maund of pucca tea per acre more than those on which banjhies were left.

TABLE XII.

The effect of Plucking Bhanjhies.

Treatment.	Yield in Maunds of Made Tea per acre.		
	1925	1926	Total 1925-26.
BJ +	9.2	9.4	18.6
BJ -	9.2	8.6	17.8

As before, also, the bushes on which banjhies were left produced the thicker pruning wood, though it will be observed that this also occurred in 1925, when the yields from the two sets of bushes were equal.

Table XIII gives the results in detail.

TABLE XIII.

The effect of Plucking Banjhies.

Treatment.	Series.	1925		1926	
		Tea. Yield in Maunds per acre.	Wood. Diameter in inches.	Tea. Yield in Maunds per acre.	Wood. Diameter in inches.
BJ +	First	10.1	.200	9.4	.232
	Second	9.0	.199	9.8	.246
	Third	8.5	.224	9.0	.233
BJ -	First	9.9	.212	8.4	.243
	Second	9.6	.211	8.1	.245
	Third	8.3	.230	9.3	.244

Irregularities are again observable, occurring in the second series, the irregularity being in crop in 1925, and in thickness of wood in 1926, and in the third series, in which the bushes on which banjhies were left gave the bigger outturn in 1926. The wood is not consistently thicker where the crop taken has been less, nor where banjhies have been left, though this has generally been the case. It was consistently thicker in 1926 than in 1925.

SUMMARY.

It is noticeable that the observations made in 1925 and 1926 confirm most of the indications deduced in the previous note on the result of these experiments.

Allowing the bushes to continue to make growth after plucking has commenced has resulted in a decrease of crop.

This has occurred whether the continued growth has been the result of the class of plucking adopted, or of leaving banjy shoots on the bush.

The effect of breaking back on the yield continues to be irregular, and the benefit of this procedure, from the point of view of outturn, to become more doubtful.

When the results are considered as a whole, it seems to be indicated that, as a general rule, thicker pruning wood accompanies a lower yield, but that this is not necessarily so.

The detailed observations indicate that, though there is a tendency for the effect of a treatment, where that is marked, to proceed in the same direction over a series of years, it may, in any given year, be entirely reversed for some reason probably entirely outside the scope of the experiment. Results based on one year's observations are therefore of no value.

The results show, beyond question, that whatever the treatment the plots received, they made better wood in 1926 than in 1925, and this occurred whether they yielded more or less leaf in one year than in the other.

Observations regarding thickness of wood are therefore only comparable if made in the same year, and the season exercises a profound influence on the thickness of the wood obtained.

The experiments are being continued.

SOIL BACTERIA IN RELATION TO CULTIVATION AND MANURING.

BY

S. F. BENTON.

The object of this article is to point out the importance of bacteria as a definite factor in the cultivation and manuring of the tea bush.

The soil is usually considered as a mixture of particles of various sizes which are classified as coarse sand, fine sand, silt, fine silt, and clay, together with small amounts of organic matter and salts necessary for the growth of plants. This type of analysis gives the idea that the soil is a dead substance acting merely as a support and a reservoir of food for the roots of plants.

A brief examination of the facts shows that this view is incorrect. It is well known that plants can only take up from the soil substances in solution. Being soluble in water, these substances can all be washed out by rain, though in some cases, this leaching takes place very slowly. In any case it is obvious that unless some factor is constantly at work converting complex insoluble substances into simple soluble salts, all plants would sooner or later die of starvation.

A normal top soil contains bacteria and fungi in very large numbers, and these are quite indispensable for agriculture. Not only are they engaged in breaking down manures and dead matter, and in producing soluble phosphates from the soil particles, but certain groups take nitrogen from the air and leave it in the soil in a combined form, thus helping to preserve the fertility of the soil.

Three large groups of micro-organisms are found in the soil.

Types of
micro-organisms
in the soil.

These are called Fungi, Actinomycetes and Bacteria. The fungi are mainly concerned with the destruction of wood, and their efficiency in this respect may be judged by the

rate at which tea prunings disappear after hoeing in. These fungi must not be confused with those which produce diseases of the tea bush. The latter attack living tissues, frequently causing the death of the bush. The true soil fungi only attack matter which is already dead, and are unable to grow on living tissues except in rare cases.

With the actinomycetes or "ray fungi" we are not particularly concerned in this article. They are chiefly of interest because they are responsible for the "earthy" smell of soil, which is most marked after rain.

The bacteria carry out a much wider range of changes. Certain of them break down complex manures and the remains of dead plants and animals, converting the nitrogen to ammonia; others convert this ammonia to nitrate. Others take the nitrate out of the soil while engaged in breaking down green manures and jungle which has been hoed in. Another group changes the soil nitrates and ammonia to free nitrogen which goes into the air and is lost;—the activities of these bacteria must be controlled. Nitrogen fixing bacteria fix nitrogen from the air,—one of the most valuable processes known. Sulphur bacteria convert sulphur to sulphuric acid—hence the treatment sometimes advised, of adding sulphur to a soil to increase its acidity.

In short there are few processes connected with agricultural practice in which bacteria do not play an important part.

The conditions in a normal jungle soil, before cultivation is commenced, are as follows. Bacteria in the soil produce nitrates, which are taken up almost completely by the heavy growth of plants and trees. From the trees, dead leaves and branches fall on the soil, adding large quantities of organic matter and nitrogen.

The causes of soil deterioration.

The organic matter is attacked by fungi and bacteria, the major portion being decomposed and given off into the air as carbon dioxide, which is again taken up by the green jungle. The nitrogen in the remainder is converted to nitrate by bac-

teria, and in this form once more enters the plant through the roots. The presence of organic matter in large quantities stimulates nitrogen fixation, and the soil steadily becomes richer, jungle growth increasing in proportion.

The increasing growth of jungle roots, however, has the effect of restricting bacterial activities, so that the amount of available nitrogen becomes progressively less. Eventually a point is reached at which the mineral food supplied, through the agency of the bacteria, is just sufficient to support the existing jungle, which in turn supplies little more organic matter than is necessary for the bacteria themselves.

Equilibrium having been established in this manner, there is the minimum of wastage, and soils in this state will remain for long periods without radical change in their composition, unless the cycle is upset, *e.g.*, by fire or floods.

The jungle is now cut down to form a tea garden. The trees and branches are removed and the smaller plants are buried or burnt. The soil is thus deprived of its normal source of organic matter. The land is hoed to destroy shallow rooted jungle and, the bacteria being now free to act without hindrance, decomposition sets in at a tremendous rate. Nitrates are formed much more rapidly than they can be absorbed by the tea and are washed out by rain. According to Mann, new tea gardens on very rich soil may give poor quality for some years, on account of the excessively coarse growth brought on by the accumulation of nitrates.

The amount of nitrogen lost in this way may reach alarming proportions as may be seen from the following figures (Mann.) :—

Period under tea.	Weight of nitrogen in virgin soil. lbs. per acre.	Loss of nitro- gen in lbs. per acre.	Annual loss of nitrogen in lbs. per acre.
(1) 10 years ...	7,000	1,500	150
(2) 35-40 years ...	10,000	5,500	157
(3) 28 years ...	7,000	1,500	57.7
(4) 20 years ...	13,000	3,000	150

The amount of nitrogen removed in an eight-maund crop is about 30 lbs. per annum and a little more is used in building the frame of the bush, so that a total loss of up to 130 lbs. per acre per annum may occur. During the early life of the garden this annual loss is probably very much higher, since the most readily available nitrogen is attacked first.

Much of the nitrogen in a soil is very resistant to bacterial attack, so that a soil which still contains 3,000 lbs. of nitrogen per acre may grow very poor tea, while the addition of only 40 lbs. per acre of a soluble form of nitrogen, *e.g.*, sulphate of ammonia or sodium nitrate, may bring about a 50 per cent. increase of crop.

In soil No. 2 above, for instance, the loss of 5,500 lbs. out of 10,000 lbs. per acre may represent almost complete exhaustion of the available nitrogen in the soil.

Cultivation also brings about a marked increase in the rate of decomposition of the soil's organic matter, and in a comparatively few years a rich soil may deteriorate considerably.

To preserve the fertility of the soil, the nitrogen and organic matter content must be maintained and this is best effected by making use of the soil bacteria.

The loss might be made good by the extensive use of artificial fertilisers alone, but the cost would be prohibitive. To take an example let us assume that the soil is losing annually 100-120 lbs. of nitrogen per acre. To replace this with ammonium sulphate would require 5 cwt. per acre which, at the price of Rs. 180 per ton, would cost Rs. 45 per acre, plus freight.

This, however, would do nothing towards maintaining the content of organic matter, apart from stimulating the growth of jungle and bush. If oilcake were used to supply both nitrogen and organic matter the quantity required would be 28 maunds per acre at a cost of Rs. 105. Any attempt to preserve soil fertility by the sole use of artificial manures is thus economically unsound.

As mentioned above, there exist in the soil bacteria capable of taking nitrogen from the air and making it available for plants. An important group of these consists of the well known legume bacteria, which are found in the nodules on the roots of green crops such as Boga medeloa, cowpeas, dhaincha, and the like. Others live a free life in the soil and obtain their food from fresh organic matter, fixing nitrogen in return.

The most successful agricultural practice thus resolves itself into making the greatest possible use of these bacteria, and it is hoped that this article will show how these, and other valuable organisms, may best be encouraged.

The importance of bacteria in the soil having been established, their nature and mode of life will be considered, together with the application of this knowledge to agricultural practice.

The Nature and
Habits of bacteria.

Although commonly referred to as "bugs," bacteria are in reality not animals but plants of a low order, being even lower down in the scale of life than the fungi. Like the fungi, they are devoid of the green colouring matter of plants and therefore they cannot use the energy of the sun's rays directly.

In point of fact, direct sunshine is nearly always fatal to bacteria, which probably accounts for the lower numbers of these organisms in the top inch or two of soil (see below).

Their inability to use the energy of the sun direct determines their mode of nutrition. They must obtain their energy second-hand, by breaking down substances with a high energy content, *i.e.*, residues of plants and animals.

For this reason the majority of bacteria fall naturally into two groups, according as they live on living or dead matter. The first group contains the bacteria which cause diseases of living animals and plants, and the second group those which reduce the dead material to simple bodies which can once more be absorbed by plants. It is the failure to distinguish between

these two groups which has given rise to the idea that all bacteria are harmful and should be suppressed where possible. Actually, were all bacteria and fungi destroyed, life on the earth would become extinct.

The soil bacteria belong almost entirely to the second group, with the exception of a few species which live on mineral salts only.

Bacteria occur in a variety of shapes, the most common being rods of varying length, and small spheres. In addition there are "comma" and spiral shapes. They are usually found in "colonies" which may consist of a few hundred or many million bacteria. A colony of five million typical bacteria would occupy the space of a pin's head. In the soil, these colonies are usually found surrounding small particles of lime.

Although they are plants by nature, bacteria are able to move about in the soil water. By special staining methods they are seen to have long waving "arms" or flagella, and these are lashed violently backwards and forwards in the liquid, causing the organism to move at a considerable speed in relation to its size. These flagella are of special interest in connection with the bacteria of green crops.

In bacteria the simplest and most efficient form of reproduction is met. When a cell has grown to its full size it divides in two, and each of the resulting cells is exactly the same as the parent. Sexual reproduction is absent and in consequence, cross-breeding being impossible, bacteria tend to maintain their characteristics. For example, there is little difference between the nitrifying organism of Assam and that of England.

Certain bacteria also form spores which are very resistant to heat and may be boiled in water without loss of vitality.

Under favourable conditions a single cell can form two cells in half an hour. At this rate, after two days the descendants of a single cell would number 281,500,000,000. Under ordin-

ary conditions, lack of food soon slows down this rate of increase, though if food is available in large quantities the effects of bacterial growth may be marked.

This is brought out by the temporary depression of crop noticed when a green manure or paddy straw is hoed in. Enormous quantities of cellulose are put into the soil, and the cellulose bacteria increase rapidly. In so doing they remove almost the whole of the nitrates from the soil, and until the nitrogen in the green material starts to decompose, the tea suffers from nitrogen starvation. The same fact has been brought out in a laboratory experiment with oilcake. When this manure was added to soil at the rate of 8 tons per acre there was an immediate loss of 90 lbs. nitrate per acre, probably the whole of which went to feed the cellulose bacteria. All the nitrogen removed is returned to the soil when the bacteria die off, after their work is done.

In the soil, the bacteria occur in incredible numbers, a normal fertile soil containing about 100,000,000 Bacteria in the Soil. to the ounce, or approximately five thousand million million per acre. These great numbers are somewhat discounted by size—the average bacterium measuring about one twenty-thousandth of an inch in length—but they are nevertheless sufficient to make all the difference between a naturally fertile soil and one on which tea culture is only possible by constant resort to artificial fertilisers.

The numbers vary greatly with depth. The following table shows the distribution in the top two feet of soil:—

Distribution of bacteria in soil.	Depth.	Number of bacteria per ounce of soil.	
	2 inches	...	... 24,500,000
	4 "	...	... 40,800,000
	6 "	...	... 40,800,000
	12 "	...	... 1,820,000
	18 "	...	... 525,000
	24 "	...	... 100,000

Here is the explanation of the well known infertility of the subsoil. The reasons for the failure of bacteria to survive in any but the top few inches are several. Lack of air in the subsoil is one of the main factors; another is the almost complete lack of available organic matter. In addition, the soil itself behaves as a very efficient filter in preventing the bacteria from being washed down by rain, acting in the same way as the earthenware candle in the filter which is to be found in every bungalow.

These figures act as a strong condemnation of the practice of digging drains and piling the excavated earth upon the tea on either side. If new drains are to be opened in an area already under tea, the subsoil should be spread thinly over the soil for some distance on either side. Whenever it becomes necessary to deal with subsoil in large quantities it should be freely mixed with cattle manure, which will have the effect of increasing the content of organic matter while supplying a very large number of bacteria.

The same applies when it is necessary for any reason to plant up land from which part of the top soil has been removed *e.g.*, by wash.

This infertility of the subsoil is one of the main arguments in favour of terracing on steep slopes in an exposed position. The top soil with its attendant bacteria and organic matter is easily lost and may take years to replace. On gardens where the top soil has already been lost, the continued use of artificial fertilisers such as sodium nitrate and ammonium sulphate is merely putting off the day of reckoning, and the health of the bushes will be maintained only while these manures are present. The counsel of perfection would be to build up a new top soil by heavy dressings of cattle manure, green crops, and decay-jungle.

THE CONDITIONS NECESSARY FOR BACTERIAL LIFE.

There are two groups of bacteria in the soil, one of which

Air.

requires abundance of air for its life processes while the other can live in entire absence of

oxygen. The members of the first group carry on most of the

valuable processes in the soil, while those of the second group are on the whole undesirable. One species of the latter has the power of destroying nitrates and giving off free nitrogen causing a very serious loss to the soil. When the oxygen supply is insufficient these and other bacteria actually produce plant poisons so that their harmful effect on plants is twofold. It is thus necessary to restrict their activities as far as possible,

- (a) by keeping the soil in good tilth and so allowing air to penetrate freely to the greatest possible depth.
- (b) by preventing waterlogging of the soil by an adequate drainage system.

Bacterial activity is dependent on a sufficient supply of moisture in the soil. For the best working, the moisture content must lie between certain limits. Thus at Tocklai the optimum moisture content for the nitrifying bacteria is near 14 per cent. (*i.e.*, 35 per cent. of saturation). When the moisture content falls to 10 per cent. (25 per cent. of saturation) in the cold weather, bacterial action is checked, and the bush is left without its normal food supply. Similarly when the moisture content rises to near the saturation point, the activities of bacteria are greatly restricted, and unless steps are taken to remove the excess water by drainage, a race of harmful bacteria may take possession of the soil. The disappearance of excess moisture from a well drained soil is brought out by the following figures :—

Date.			Rainfall.	Percentage of moisture in soil.
May	27th	...	0.24"	18.41
"	28th	...	nil	17.27
"	29th	...	0.05"	.....
"	30th	...	nil	16.30
"	31st	...	nil	14.40
June	1st	...	nil	13.89
"	2nd	...	1.72"	18.38

Thus under dry conditions the moisture content of the soil falls fairly rapidly until it reaches the optimum. From other figures it is found that below this point the soil holds on to its moisture with greater tenacity.

The actual degree of saturation most favourable to bacteria appears to vary in different soils, usually lying between 40 per cent. and 60 per cent. The following figures illustrate this point.

Degree of saturation.	Production of nitrates from peptone by bacteria (milligrams per 100 gms. of soil).		
	Tocklai.	Amluckie.	Red Bank.
35 %	7.36	.....	.....
40 %	6.05	7.14	8.52
45 %	4.90	8.24	9.89
50 %	4.39	8.79	16.48
55 %	3.57	10.44	13.20
60 %	.....	12.36	7.70

To preserve the maximum fertility, the soil moisture must therefore be kept as near as possible to the optimum :—

- (1) by adequate draining to remove excess water during the rains.
- (2) by the use of the cold weather mulch to maintain the moisture content at the highest possible level during the cold weather.

Prolonged droughts such as occur fairly frequently in the tea districts of the Terai and South Sylhet may cause a serious destruction of soil bacteria, leading to a slow recovery of the bush. When possible it is as well to apply a dressing of cattle manure on weak sections after a severe drought, as this will have the double effect of supplying food for the bush while adding a large number of active bacteria to the soil. If the drought has not been too severe, the effect of the first rain is most marked. The nitrate content of the soil, which has remained at a very low level throughout the cold weather, suddenly jumps up to nine or ten parts per million. This sudden increase doubtless plays a considerable part in bringing on the first flush.

The food requirements of the majority of soil bacteria may be placed under two headings, *viz.* :—

Food.	Organic matter.	Lime.
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Lime does not act so much as a true food, but rather as a neutraliser of the acids produced by the bacteria in their normal life. This will be discussed below.

Organic matter is used by bacteria in enormous quantities. For example, American workers have found that the nitrogen fixing bacteria when supplied with straw as their food fix $7\frac{1}{4}$ lbs. of nitrogen from the air while decomposing a ton of straw. When the green matter from clover was supplied instead of straw, the amount of nitrogen fixed was about 27.5 lbs. per ton of material decomposed. It is probable that the results with the green manures in use in the tea districts would be comparable with the latter figures, but work on this point has not yet been carried out.

From these figures it appears that the amount of nitrogen fixed by the soil after a green crop has been hoed in would be in the neighbourhood of 80 lbs. per acre, apart from the 20 lbs. fixed by the crop itself. It must be pointed out that these figures were obtained as a result of laboratory experiments and in the field different results might be obtained. From a good crop a gain of at least 100 lbs. nitrogen per acre is to be expected, which compares very favourably with the usual dressing of 30 lbs. given as ammonium sulphate.

The organic matter requirements of bacteria are seen to be very large. Under jungle conditions, these requirements are supplied by the annual leaf fall from trees and by the succession of low-growing grasses. On the tea garden, however, jungle must be suppressed for it competes with the bush for food. The depression caused by jungle is well brought out by the following figures obtained from the Borbhetta cultivation plots.

Plot No.	Treatment.	Relative efficiency of nitrifying bacteria.	Crop 1926.
87	Monthly cheel	201.0	10.60
93	6 light hoes	176.7	10.16
88	1 light hoe. Extra manure	141.3	6.16
95	Sickled only	100.0	3.68

Plot 87 is kept free from jungle. 93 is nearly free while on 88 and 95 jungle is plentiful. It is interesting

to note that the presence of jungle has had harmful effects on the soil bacteria as well as on the tea. This is possibly due to toxins given off by the jungle roots.

On the contrary, the practice of growing shade trees is very beneficial. The roots of the trees are too far below the surface to have much effect on the bacteria in the top few inches of soil. The wide-spread root system does much to minimise the loss of nitrates and soluble salts which would otherwise take place through leaching, and finally the tree itself deposits annually a large amount of organic matter, containing some 3 per cent. of nitrogen.

From the figures given above it is clear that the suppression of jungle is one of the most important factors in tea garden management. Undoubtedly the best method of effecting this is to grow tea bushes that touch each other so that jungle has no chance to grow—while the organic matter content of the soil is partially maintained by leaf fall and prunings. This is a counsel of perfection not easy to follow on gardens with a large percentage of deteriorated tea and vacancies, but approximated to on very large areas of good tea.

Jungle is usually eliminated by the use of the light hoe. Unfortunately the light hoe is very wasteful of the soil reserves for it is followed by a sudden increase in nitrates amounting to some 20 lbs. per acre (on Tocklai soil). A heavy fall of rain following cultivation will remove almost the whole of this and the soil will be poorer in proportion. The destruction of organic matter is stimulated in a similar manner.

This loss after light hoeing is avoided to a considerable extent by substituting "cheeling" or cultivation with a spring-tine harrow and buffalo, both of which effectively suppress jungle while disturbing the soil to a depth of a few inches only. The possibility of using either of these forms of cultivation depends largely on circumstances, labour being concerned in the former case, and the drainage scheme, transport facilities, and distribution of shade trees in the latter.

The fact remains that cultivation causes considerable losses of nitrogen. These can be made good in two ways, *viz.*—by addition of manures and by nitrogen fixation. Nitrogen fixation is, however, dependent on the amount of available organic matter. It is therefore clear that above all things the organic matter content of the soil must be kept up, if the bacterial population is to be kept in good working order. This fact is so important that a manuring scheme taking no consideration of the soil bacteria may be considered incomplete.

The tendency of late years has been to rely more and more on the purely artificial fertilisers such as Sulphate of ammonia and Calcium cyanamide for the nitrogen supply, chiefly on account of their low cost. It is important to remember that these manures are added solely with the idea of increasing the crop, and that they have little or no direct beneficial effect on the soil bacteria. A programme incorporating these manures must always include regular green cropping or dressings of cattle manure, preferably well-rotted with paddy straw.

For the majority of bacterial processes a neutral or slightly
lime. alkaline soil is required. Tea requires an
acid soil and anything approaching neutrality
appears to be definitely harmful. On the other hand, the fertility of the soil depends largely on the activities of the bacteria, to which lime is an essential. The difficulty is met by a compromise, lime being added in quantities insufficient to change the reaction of the soil, but under conditions where it will have most effect on the bacteria. To take an example, let us consider a typical tea soil with a "Hopkins acidity" of 400. This means that 400 lbs. of lime would be required to bring 1,000,000 lbs. of soil to a condition of neutrality. Taking the weight of an acre of soil to a depth of nine inches as 3,000,000 lbs., we find that this soil would require 1,200 lbs. lime per acre to make it neutral.

Now five maunds of crushed limestone contains about 200 lbs. of free lime, so that this amount could be supplied per acre without making any appreciable difference to the acidity of

the soil, although being of great value to the bacteria. The best time to add lime is before sowing a green crop, so benefiting the green crop itself and also the bacteria on whose presence and activity the efficiency of the crop depends. The lime should be distributed only in the rows where it is intended to sow the green crop, and preferably in the seed-bed itself.

Experiments conducted at Borbhetta showed that on this particular soil, Rahar would not grow at all without lime. When this deficiency was made good the crop obtained increased with increasing amounts of lime, until a dressing of 80 maunds of crushed limestone produced a Rahar crop of 250 maunds per acre.

The Tocklai lime policy thus becomes comprehensible when considered in terms of bacteriology. Continual applications of lime over a period of years, or the application of a large dressing is seldom, if ever, advised, but small dressings are recommended from time to time to satisfy bacterial requirements.

The conditions for optimum bacterial working may now be summarised :—

Aeration of the soil.

Ample moisture, but avoidance of excess by draining.

Plentiful supply of foodstuff in the form of organic matter.

Suppression of jungle.

Small amount of lime at intervals on the more acid soils.

The space available will not allow of a description of all the bacterial processes taking place in the

Green Manuring.

soil. As the practice of green manuring is of great importance in tea soils, the relation of bacteria to green manures will be dealt with more fully here, and a discussion of other bacterial processes will be left till later.

It is generally realised that bacteria are intimately connected with green manures. On the roots of all members of the legume family may be found small nodules. These vary in numbers with different species of plants, and with different conditions of growth.

If one of these nodules be cut in two, it is found to consist of an outer white layer of firm consistency, surrounding an inner mass, often pink in colour, which is soft and slimy. This inner mass is seen under the microscope to consist of enormous numbers of slender bacteria, entirely filling the cells of the nodule. It is to these bacteria that the legumes owe their value as green manures, for, as stated above, they have the power of taking nitrogen from air, building it into complex soluble substances, and passing these on to the plant. In return for these substances, the plant supplies the bacteria with sugars, water and salts—substances which enable the bacteria to carry out their work of nitrogen fixation.

There is here a perfect example of division of labour.

The ordinary green plant takes up its nitrogen as nitrate or ammonia. On this account jungle competes with the tea bush for food, and as it has its roots mainly in the top few inches of soil, where bacterial action is at its highest, the jungle has first call on the food supply.

The necessity of bacteria for economical growth of green crops.

Hence, apart from reasons of convenience, jungle must be suppressed.

A green crop without nodules acts in the same way as jungle, the rate of growth and final crop being determined by the amount of nitrate and ammonia in the soil. Consequently any growth of a green crop without root nodules is at the expense of the tea.

If nodules are present on the roots, the position is altered. The bacteria in the nodules draw relatively large quantities of nitrogen from the air, and with the aid of this nitrogen the plant grows far larger than it would were it living on soil nitrates alone. For successful green crops the requirements of the bacteria must be studied and met.

The bacteria are mainly present in the soil in an inactive state. They possess no power of moving through the soil and little power of infecting roots of legumes. When a soluble phosphate is supplied the bacteria develop flagella, become highly

active and are able to infect the plants readily. The use of phosphate is therefore a wise policy wherever green crops are to be sown, and many cases of failure may be put down to the neglect of this precaution. The best phosphates to use are Basic slag, Superphosphate, Belgian flour phosphate and Algerian phosphate. The quantities usually recommended are as follows :—

Superphosphate	...	...	2 mds.	per acre.
Basic slag	...	...	2	” ”
Belgian phosphate	...	...	3	” ”
Algerian phosphate	...	...	2	” ”

From the above remarks it is clear that the value of a green manure depends on the extent of infection by bacteria. The question now arises, whether the legume bacteria in the soil are present in sufficient numbers to secure the maximum infection. In some districts it is found almost impossible to grow a good green crop and the idea suggests itself that lack of bacteria may be the cause. If this is so, artificial inoculation of the soil or the seed might be resorted to with success. So far, little work has been done along these lines in the tea soils. A few isolated trials were made in the Tocklai district this year with varying results. The bacteria were grown on an agar (china-grass) jelly, and just before planting, the seed was moistened with a suspension of these bacteria in water.

Cowpeas gave poor results. Not only was it found difficult to grow the bacteria, but the inoculated plants were barely as good as the uninoculated. Boga medeloa was unsatisfactory owing to unfavourable climatic conditions and practically the whole crop failed. With dhaincha more promising results were obtained. The results of the experiments were :—

Yield from 11 rows uninoculated.	Yield from 11 rows inoculated.
590 lbs.	918 lbs.

Increase from inoculation 328 lbs = 55.6 per cent.

The seed was planted in alternate rows, alternate rows of seed being inoculated. Phosphate was not supplied and the soil in the section was poor. In almost every case, an inoculated row gave a greater weight of green material than the uninoculated rows on either side.

Definite conclusions cannot of course be drawn from a single experiment of this nature. This Department will be pleased to get into touch with any planter who has continual difficulty in establishing a green crop and who would like to carry out experiments in inoculation.

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The science of agriculture has passed through three main stages in the course of its development. In ancient times the Mechanical stage held the field. Improvements were chiefly along the lines of cultivation and drainage, although a considerable amount was known about fallowing and the use of green manures such as clover in a crop rotation. At the beginning of the nineteenth century agriculture passed definitely into the Chemical stage and tremendous advances were made in the science of manuring; during the closing years of the same century the Biological era arose and gained favour in so rapid and sensational a fashion that there was a tendency in certain circles to regard bacteria as the beginning and end of agriculture.

Actually there are no hard distinctions to be drawn. The mechanical, chemical, and biological phases are all intimately connected and interdependent, and a change which affects one will affect all.

In this article the claims of the bacteria have been put forward. Their importance in soil fertility has been brought out and the conditions they prefer have been enumerated. No attempt has been made to deal at length with individual bacterial processes in the soil, but the importance of organic matter has been emphasised, since this substance is the chief food, directly or indirectly, of the majority of soil bacteria; and on these, eventually, the economic cultivation of the tea bush depends.
